NUCLEAR SCIENCE AND TECHNIQUES **25**, S010606 (2014)

Analysis of the influence on environmental radiation level of Qinshan area caused by Fukushima nuclear accident

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(Received June 30, 2013; accepted in revised form October 25, 2014; published online November 20, 2014)

In order to monitor the diffusion and deposition of radioactive plume in Qinshan area after Fukushima nuclear accident, a continuous air sampling was did from March 25 to May 6. A trace of ^{134}Cs and ^{131}I were detected in the period. Results of conventional environmental radiation monitoring also showed that the specific activity of ^{90}Sr and ^{137}Cs in environmental samples had some abnormal changes in 2011 which almost felt back to normal level in 2012. Although there is no abnormal change on environmental radiation level of Qinshan area till now, the influence caused by Fukushima nuclear accident should be paid continuously attention in future by radiation monitoring.

Keywords: Fukushima nuclear accident, Qinshan area, Environment radiation monitoring

DOI: 10.13538/j.1001-8042/nst.25.S010606

I. INTRODUCTION

On March 11, 2011, a serious 7-level nuclear accident happened at Japan Fukushima Daiichi nuclear power plant caused by tsunami and earthquake. A huge amount of radioactive materials were released causing a serious off-site consequence. China National Nuclear Accident Emergency Coordination Committee issued on March 31 announced that 25 provinces and districts in China had monitored trace amount of ^{131}I or other artificial radioactive nucleus [1, 2]. The straight-line distance between Fukushima Daiichi nuclear power plant and Qinshan nuclear power base is about 2300 km. Due to the diffusion by wind and ocean currents, part of radioactive materials is very like to have spread to Qinshan area.

"Qinshan area" means the scope of a radius of 10 km and the center of the circle is the 300 MWe units around the Qin-Shan nuclear power base. ^{3}H, ^{14}C, ^{90}Sr, ^{137}Cs, ^{131}I and γ nuclides are analyzed [3–5]. The sampled mediums are as follow:

- Environmental γ radiation;
- Air and fallout (aerosol, fallout and rain);
- Soil (land surface soil, mud of seabed and beach soil);
- Agriculture products (tea, green vegetable, milk, herbage, rapeseed, mulberry, radish, rice, goat, green soybean);
- Aquatic products (mullet, hair tail, jellyfish, shrimp, spiral shell);
- Water (seawater, drinking water, pond water, underground water);
- Biological indicators (pine needle, oyster, moss) [6].

In addition, it also provides Qiaosi (WSW, 60 km), Hangzhou (WSW, 100 km) and Zhoushan (ESE, 140 km) as our environmental references, where we can collect herbage, milk, fallout, tea and seafood. They are located in the small frequency distribution range of wind direction from wind field of nuclear power plants. The distance from nuclear power plant is far enough and not affected by other radioactive facilities or industrial pollution. So, environmental references are not affected by the operation of nuclear facilities. While analyzing of the influence on environmental radiation level of Qinshan area caused by Fukushima nuclear accident, they are strong references.

II. ANALYSIS OF THE INFLUENCE ON ENVIRONMENTAL RADIATION LEVEL OF QINSHAN AREA CAUSED BY FUKUSHIMA NUCLEAR ACCIDENT

There are 5 pressurized water reactors (PWR) and 2 heavy water reactors (HWR) operated in Qinshan area. In order to identify the effects caused by Fukushima nuclear accident, a parallel contrastive analysis on the data was made, focusing on specific activity changes of ^{90}Sr, ^{134}Cs, ^{137}Cs and ^{131}I in the medium samples.

A. Emergency and intermediate phase

In order to monitor the diffusion and deposition of radioactive plume in Qinshan area after Fukushima nuclear accident, a continuous air sampling at 7 monitoring positions (Fig. 1) was did from March 25 to May 6, 2011. So the early effect of the Fukushima nuclear accident could be detected in Qinshan area.

1. ^{90}Sr, ^{134}Cs and ^{137}Cs *in aerosol samples*

Aerosol and gas iodine are joint sampling, continuous pumping 72 h and the sample volume of air is about 600 m^{3} every time. To analyze ^{90}Sr and ^{137}Cs in aerosol samples, all of the samples in one quarter should be gathered and analyzed by radiochemical method. Obviously in second quarter of 2011, just after the nuclear accident, the specific activity of

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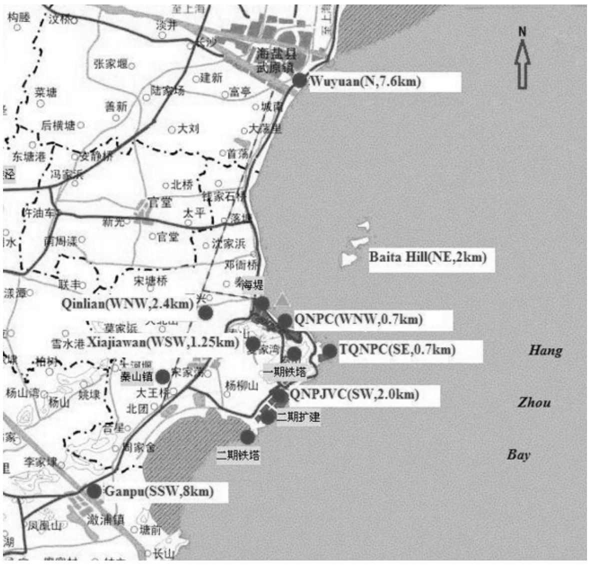

Fig. 1. Map of air monitoring positions.

^{137}Cs in aerosol samples is tenfold higher than usual. The γ spectrum analysis of aerosol samples showed that a trace of ^{134}Cs existed in air which can not be detected in air sample before the accident.

2. ^{90}Sr and ^{137}Cs *in fallout samples*

Fallout samples are collected monthly. Before and after the nuclear accident, the specific activity of ^{90}Sr, ^{137}Cs in fallout samples remained the same order of magnitude.

In second quarter of 2011 after the Fukushima nuclear accident, the specific activity of ^{90}Sr in fallout samples is higher than usual. For example, the values of Xiajiawan (WSW, 1.25 km) and Qinlian (WNW, 2.4 km) are tenfold higher than 1st quarter of 2011, and the values of last three quarters of 2011 after the accident are all higher than MDC (MDC of ^{90}Sr in fallout samples equals 1.3 mBq/dm^2). The specific activity of ^{90}Sr and ^{137}Cs in fallout samples from Qiaosi (WSW, 60 km) remains the usual level.

3. ^{131}I *in air samples*

From March 25 to May 6, according to the method from GB/T14584-1993, we have detected a trace of ^{131}I in air samples (Fig. 2). Usually the specific activity of ^{131}I in air samples is less than MDC which equals to 0.10 mBq/m^3. From April 3 to 6, the specific activity of ^{131}I in air samples has reached the top which equals 2.73 mBq/m^3.

4. *Other samples*

The γ spectrum analysis of iodine boxes showed that not only ^{131}I but also ^{134}Cs and ^{137}Cs existed in the activated carbon boxes. From April 3 to 18, the specific activity of ^{134}Cs and ^{137}Cs absorbed by iodine boxes are higher than MDC which equal to 0.04 mBq/m^3 and 0.07 mBq/m^3 (Figs. 3 and 4).

In April of 2011, drinking water samples were analyzed. The radioactivity measurement results have no abnormal change. Through analysis of rain, fallout and air samples, the Fukushima nuclear accident had no effect on ^{3}H, ^{14}C and total α/β results.

Above all, after the Fukushima nuclear accident, the specific activity of ^{137}Cs of air and fallout samples is significantly higher than usual. And especially in the second quarter of 2011, a trace of ^{134}Cs and ^{131}I have been detected in Qinshan area. At the same time, Qinshan nuclear power base is operating normally. It proves that part of radioactive plume released from Fukushima nuclear accident had diffused to Qinshan area.

III. LONG-TERM PHASE

In the long-term phase of nuclear accident, radioactive plume have been deposited into soil, plant and groundwater circulation system [7]. Radioactive materials diffused by sea have been taken by plankton into the food chain cycle or deposited in seabed. Therefore, internal exposure caused by ingestion of food and water is the most important monitoring object.

A. Soil samples

The specific activity of ^{137}Cs and ^{90}Sr in land surface soil samples from Qinlian (WNW, 2.4 km) and Qiaosi (WSW, 60 km) is just a little higher than usual which also has the same order of magnitude as usual. Till now the Fukushima nuclear accident had no abnormal effect on mud of seabed and beach soil. The migration trend of ^{90}Sr and ^{137}Cs in soil still need continuous monitoring in future.

B. Agriculture product samples

Agricultural product is an important ingestion pathway of internal exposure. A trace of ^{134}Cs was detected in rapeseed, tea, herbage and green vegetable samples in 2011. The specific activity of ^{134}Cs in rapeseed sample from Qinlian (WNW, 2.4 km) equals to (26±5) mBq/kg, and in tea sample from Hangzhou(WSW, 100 km) it equals to (190±10) mBq/kg. Also in herbage sample from Qiaosi (WSW, 60 km) it equals to (36±2) mBq/kg.

A trace of ^{131}I was also detected in green vegetable, herbage and milk samples. The specific activity of ^{131}I in herbage sample from Qiaosi (WSW, 60 km) and Zhapu (NE, 22 km) equals to (220±20) mBq/kg and (350±30) mBq/kg.

In the meantime, the specific activity of ^{137}Cs in most green vegetable samples and herbage samples increased compared

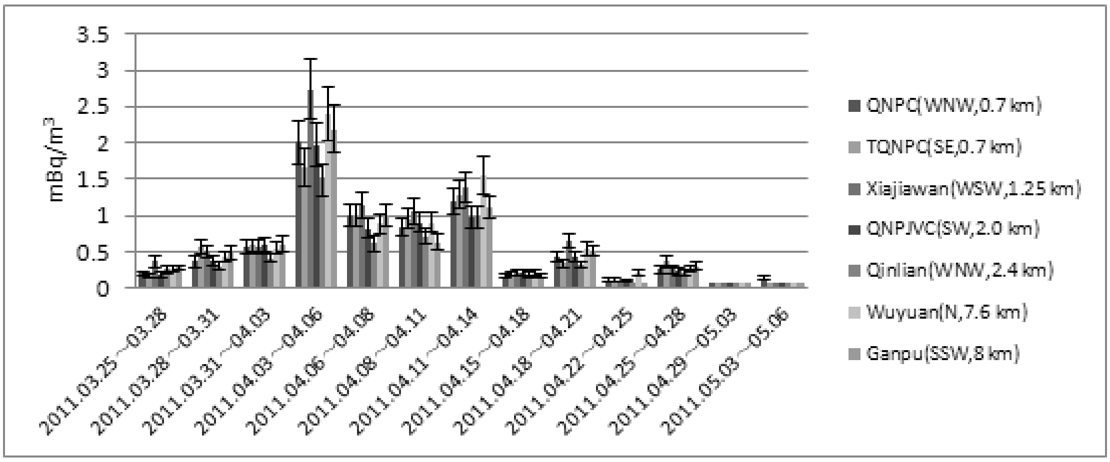

Fig. 2. The specific activity of ^{131}I in air samples (mBq/m^3).

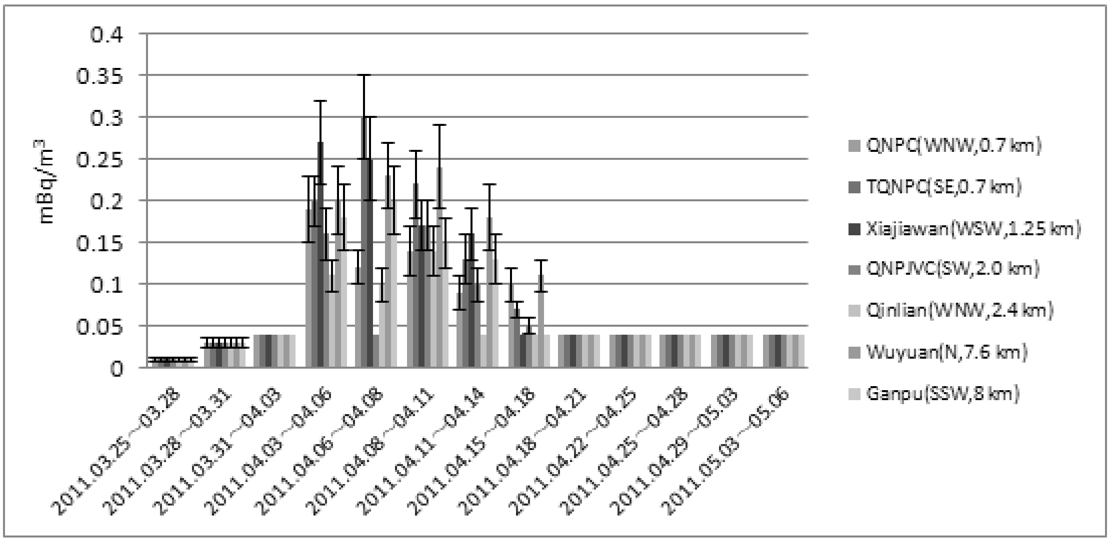

Fig. 3. The specific activity of ^{134}Cs in air samples (mBq/m^3).

with the same period in past years. So did the rapeseed samples from Qiaosi (WSW, 60 km). The maximum specific activity of ^{90}Sr in green vegetable samples collected in first half year of 2011 equals (657±40) mBq/kg which is nearly 4 times higher than usual. Especially the specific activity of ^{90}Sr in green vegetable samples from Qiaosi (WSW, 60 km) equals to (370±3) mBq/kg.

The specific activity of ^{134}Cs and ^{137}Cs increased after the accident in 2011 and then felt to usual level in 2012 in herbage samples from Qiaosi (WSW, 60 km). So was the specific activity of ^{90}Sr in green vegetable samples from Qiaosi (WSW, 60 km). This fully explained that migration of ^{90}Sr, ^{134}Cs and ^{137}Cs had occurred in the environment.

The specific activity of ^{137}Cs in radish samples of 2011 was slightly higher than usual. The specific activity of ^{90}Sr and ^{137}Cs in rice samples from Qiaosi (WSW, 60 km) also increased slightly. For other agricultural products such as bones of goat and mutton, their radioactive content did not change obviously.

C. Biological indicator samples

Biological indicator means that such organisms with large concentration factor for a particular radionuclide, which can indicate the pollution trend [8]. According to the ecological survey [9], pine needles, moss and oyster are specified as biological indicator of Qinshan area and nuclide such as ^{3}H, ^{14}C and ^{90}Sr were analyzed on them. After the Fukushima nuclear accident, we detected a trace of ^{134}Cs in moss of Baita Hill (NE, 2 km). The specific activity was about 180 mBq/kg in 2011, and then decreased to about 37 mBq/kg in 2012.

D. Seawater and aquatic products samples

The ocean is a huge, complex system. In the ocean, dispersion, mixing and transferring of the radioactive materials do not only depend on the physicochemical properties of ra-

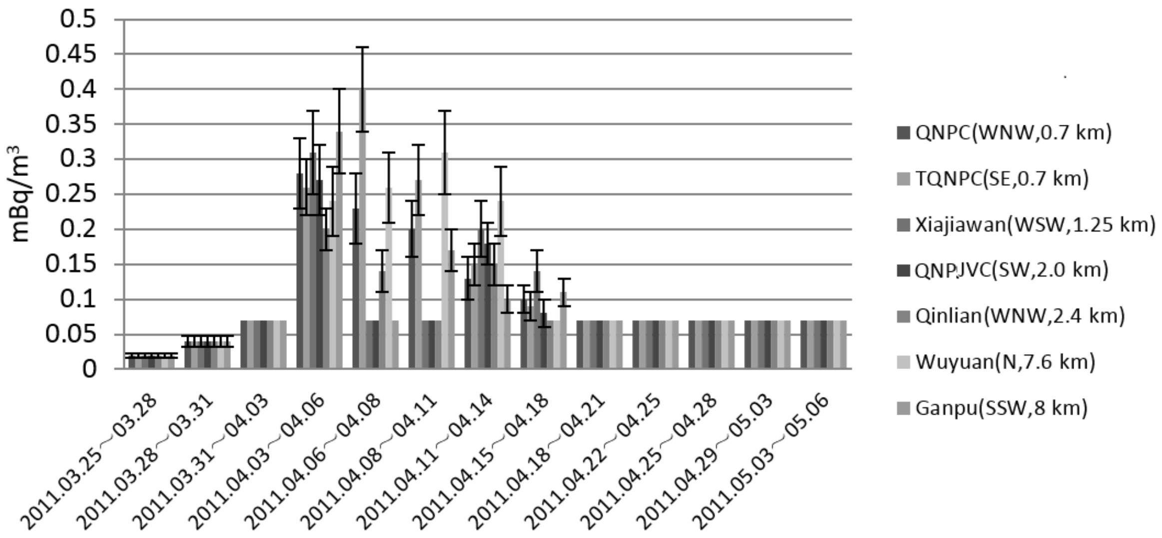

Fig. 4. The specific activity of ^{137}Cs in air samples (mBq/m^3).

dioactive material, but also depend on the emission of pollutants, sea hydraulic characteristics and hydrologic characteristics. In the ocean, radioactive substances will be accompanied by various physical, chemical and biological processes. That's a complex series of changes [10, 11].

The data of two years after the accident showed that radioactive measurement results of seawater are stable, which means that the Fukushima nuclear accident had no influence on seawater of Qinshan area till now.

Seafood is also an important ingestion way for internal exposure. Except for that the specific activity of ^{90}Sr in mullet bone samples increased year by year slightly, the rest of the radioactive measurement results have no obvious change.

IV. CONCLUSION

After Fukushima nuclear accident, a trace of ^{134}Cs and ^{131}I was detected, and the specific activity of ^{90}Sr and ^{137}Cs was bigger than usual in air. Due to the radioactive plume spread to Qinshan area is small and the diffusion duration is not long, ^{131}I wasn't detected in air samples any more from May 6, 2011. And the specific activity of ^{90}Sr, ^{134}Cs and ^{137}Cs felt back to normal level from the 3rd quarter of 2011.

Through the analysis on the monitoring of the environmental radiation level two years after the Fukushima nuclear accident, the specific activity of ^{90}Sr, ^{134}Cs and ^{137}Cs is a little higher than 2010. And ^{131}I had transferred from air to vegetables, herbage and milk. Although these nuclide mentioned above has small specific activity, and significant change of environmental radiation level is unlikely to present now. Migration changes are still worthy of sustained attention in future.

Because the territorial sea is adjacent, spiral shell as freshwater aquatic product and jellyfish as seafood were added to analyze the specific activity changes of radionuclides in seawater and seafood in Qinshan area after the Fukushima nuclear accident.

Meanwhile, Fukushima nuclear accident enlightens us:

1. Medium types of environmental radiation monitoring samples should be increased after the Fukushima nuclear accident And according to the migration of radionuclides in environment, monitoring items should be adjusted [12, 13].
2. The radiation monitoring of seawater and seafood is still needed to be strengthen in future.
3. To make precise consequence accumulation, environmental radiation monitoring program for long-term phase is needed.

[1] Wang L, Zheng G, Zhao S, *et al*. Radiat Prot, 2012, **11**: 325–335, 347. (in Chinese)

[2] Zong L, Yan D. Fukushima nuclear accident impact on China and related countermeasures. The 9th session of early 21 century radiation protection forum. 2011-09-26.

[3] EJ/T 1131-2001. Regulation for environmental radiation monitoring of nuclear power plant.

[4] HJ/T61-2001. Technical criteria for radiation environmental monitoring.

[5] GB6249-2011. Regulations for environmental radiation protection of nuclear power plant.

[6] EJ527-1990. Basic regulation for biological sampling in environmental radiation monitoring.

[7] PAN Z. Ionizing radiation environment monitoring and assessment. Beijing: Atomic Energy Press, 2007, 649-650.

[8] Qian D. Atom Energy Sci Technol, 1987, **4**: 487–490. (in Chi-

nese)

[9] HOU A. Survey report of environmental radioactive background in Qinshan region. China Nucl Sci Technol Report, **1994**, 705–728.

[10] Zhang Y, Li H, Zhu C. Ship Sci Technol, 2010, **12**: 76–79. (in Chinese)

[11] Li B, Yang D, Chen X, *et al*. Radiat Prot, 2012, **32**: 398–403. (in Chinese)

[12] Chen X, Li B, Yu S. Radiat Prot, 2012, **32**: 348–361, 372. (in Chinese)

[13] Zhang J, Yao R, Ren X, *et al*. Radiat Prot, 2012, **32**: 362–372. (in Chinese)